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Samsung Lithium Ion Battery for Uninterruptible Power Supply

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Abstract—Samsung's energy storage systems for data centres are pioneering, being the first lithium-ion battery cabinets to meet stringent UL rack-level safety standards. Integrating an Uninterruptible Power Supply (UPS) with an energy storage system is essential for ensuring reliable power to critical loads. Samsung lithium-ion battery systems are engineered to exceed the demands of large-scale UPS applications. This paper reviews, implements, and analyses Samsung lithium-ion batteries compared to lead-acid batteries, particularly with the Vertiv UPS system. A 400 kVA Vertiv UPS was connected to 17 Samsung SDI lithium-ion batteries in a robust rack configuration, each rated at 30.4 Vdc and 67 Ah. Simultaneously, a lead-acid battery setup consisting of forty 12V 67Ah batteries housed in a specialized cabinet was evaluated. A 360 kW resistive load was applied to the UPS output, and an external mains failure was simulated while measuring end-of-discharge time. Results showed that the Samsung SDI lithium-ion battery system reached a cut-off voltage of 393.5 VDC at 954.0 A, achieving 58 minutes of runtime, while the lead-acid system recorded 395.2 VDC at 962.0 A, lasting 49 minutes. These findings confirm the superior performance of lithium-ion batteries in UPS applications, reinforcing their role in data centre energy storage.

Keywords: BMS, Data Center Viability, Lead Acid Battery, Results, Samsung Li-ion Battery, Vertiv UPS.

INTRODUCTION

Samsung SDI's Lithium-Ion Battery System is composed of several key components that work in synergy to ensure efficient energy storage and management. At the core of the system are the Battery Modules, which come in two variations, Type A and Type B, designed to accommodate different configurations and installation requirements. These modules serve as the primary storage units, housing lithium-ion cells that deliver reliable energy output. Supporting the battery modules is the Battery Control Unit (BCU), which plays a crucial role in monitoring and managing the overall performance of the system. Embedded within the BCU is the Rack Battery Management System (BMS), responsible for ensuring safe operation by overseeing key parameters such as voltage, temperature, and charge levels. The system is structurally supported by a Rack Frame, which provides a stable mounting platform for the battery modules and associated components while also facilitating proper grounding for safe operation. Additionally, the Switched-Mode Power Supply (SMPS)

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Assembly, available in Type A and Type B configurations, converts incoming power to appropriate levels needed for efficient battery management. Finally, the System BMS, which is integrated within the SMPS Assembly Type A, serves as the central intelligence of the system, coordinating communication between components and optimizing overall energy distribution and safety mechanisms.

Battery Module (Type A / Type B)

The battery module is the fundamental component of the Battery System. It consists of battery cells that are connected in series and/or parallel, which store electrochemical energy, along with a module Battery Management System (BMS). The module BMS monitors various battery characteristics, including cell voltage and temperature, and keeps track of the status of each individual battery. The module BMS digitizes the voltage and temperature data for each cell, sends this information to the rack BMS, and receives commands from the rack BMS to manage cell balancing. Communication between the module BMS and the rack BMS occurs through the Serial Management Unit (SMU) via a UART interface. There are two types of battery modules based on the positioning of the terminal polarities. A Type A module, as shown in Figure 1(a), has its positive (+) terminal on the right side when viewed from the front. In contrast, a Type B module, illustrated in Figure 1. (b), has its positive (+) terminal on the left side. Figure 1(a) and Figure 1(b) in the article depict two variations of the Samsung SDI Lithium-Ion Battery Module, labeled as Type A and Type B, respectively. Both modules serve as the fundamental building blocks of the battery system, storing and delivering electrochemical energy while ensuring stable power output. In Figure 1(a), the Type A battery module is shown with its positive (+) terminal positioned on the right side when viewed from the front. This orientation is specifically designed to facilitate certain system configurations where terminal alignment is crucial for proper electrical connectivity. Meanwhile, Figure 1(b) illustrates the Type B battery module, which has its positive (+) terminal located on the left side, providing an alternative wiring arrangement to accommodate diverse installation needs. Despite the difference in terminal orientation, both modules function identically and incorporate an integrated Battery Management System (BMS). This BMS continuously monitors and regulates key parameters such as voltage, temperature, and charge levels to enhance safety and efficiency. The visual distinction between Type A and Type B modules ensures flexible system integration, allowing for optimized rack configurations in energy storage applications

(a) (b)

Figure 1. Battery Module (a) Type A (b) Type B

Battery Control Unit (BCU)

The Battery Control Unit (BCU) gathers all data and status information from the modules within the same string. It also manages the main power line switch and facilitates cell balancing. Additionally, the BCU calculates the State of Charge (SOC) and State of Health (SOH) of the battery system.

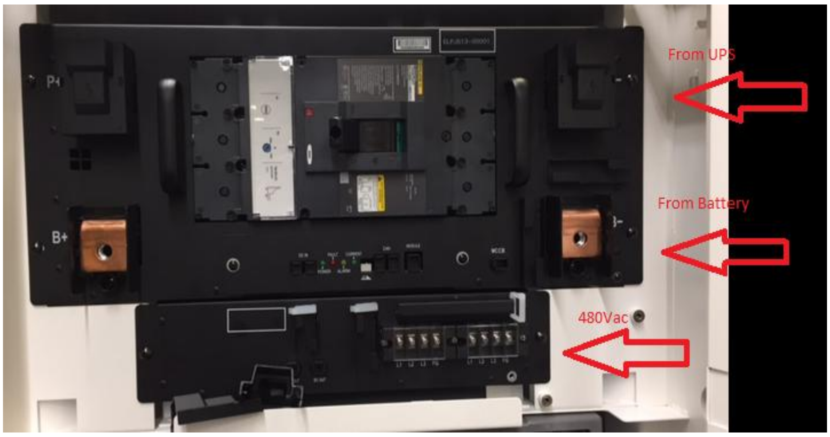


Figure 2. BCU with Optional Auxiliary Breaker Switch

Figure 2 illustrates the Battery Control Unit (BCU), a critical component in the Samsung SDI Lithium-Ion Battery System. The BCU is responsible for collecting and processing data from all battery modules within a single string, ensuring efficient power management and safety. In the image, the BCU is shown as a compact and structured unit equipped with multiple connection points for seamless integration with the battery system. A key feature of the BCU is its ability to monitor the State of Charge (SOC) and State of Health (SOH) of the battery modules, allowing for real-time assessment of energy levels and overall system health. Additionally, the unit manages the main power line switch and facilitates cell balancing, optimizing performance and prolonging battery lifespan. The image also highlights an optional auxiliary breaker switch, which can be connected to an external building monitoring system for enhanced safety and control. Furthermore, the P+ and P- terminal blocks, clearly visible in the figure, serve as the primary connection points linking the battery system to the Uninterruptible Power Supply (UPS). This well-structured layout ensures easy installation, reliable performance, and efficient communication between battery modules and the larger energy storage network.

SMPS Assembly (Type A / Type B)

The SMPS assembly is designed to house both the System BMS (when configured as Type A) and redundant SMPS units. These units are capable of accepting external AC power and efficiently converting it to DC control power, essential for the operation of the System BMS and the BCU. There are two robust options for the SMPS based on the AC input range and wiring requirements: 3-Phase AC and 1-Phase AC. The System BMS assembly plays a critical role by delivering data to external systems, including building management systems and uninterruptible power supplies (UPS), while effectively controlling and monitoring all connected Rack BMS units. A single System BMS can confidently manage up to 24 racks within a battery bank. Refer to Figure 3 for a detailed front view of the SMPS assembly. Figure 4 presents a Rack Frame populated with Battery Modules, a Battery Control Unit (BCU), and a Switched-Mode Power Supply (SMPS) Assembly. The rack frame serves as the structural foundation for mounting and securing these essential components, ensuring stability and proper electrical connections within the Samsung SDI Lithium-Ion Battery System. The image highlights the arrangement of multiple battery modules, systematically stacked within the rack to optimize space utilization and facilitate efficient power distribution. Positioned within the same framework, the BCU plays a crucial role in monitoring the performance of the battery modules, collecting real-time data, and managing critical functions such as State of Charge (SOC) and State of Health (SOH) calculations. Additionally, the SMPS Assembly is integrated into the rack, responsible for converting external AC power into DC control power, which is essential for the operation of the BCU and other system components. The rack frame also includes grounding connections, which are mandatory for ensuring electrical safety and minimizing the risk of system malfunctions. This structured configuration enhances the overall efficiency, scalability, and safety of the lithium-ion battery system, making it well-suited for high-performance energy storage applications in data centers and critical power backup solutions.

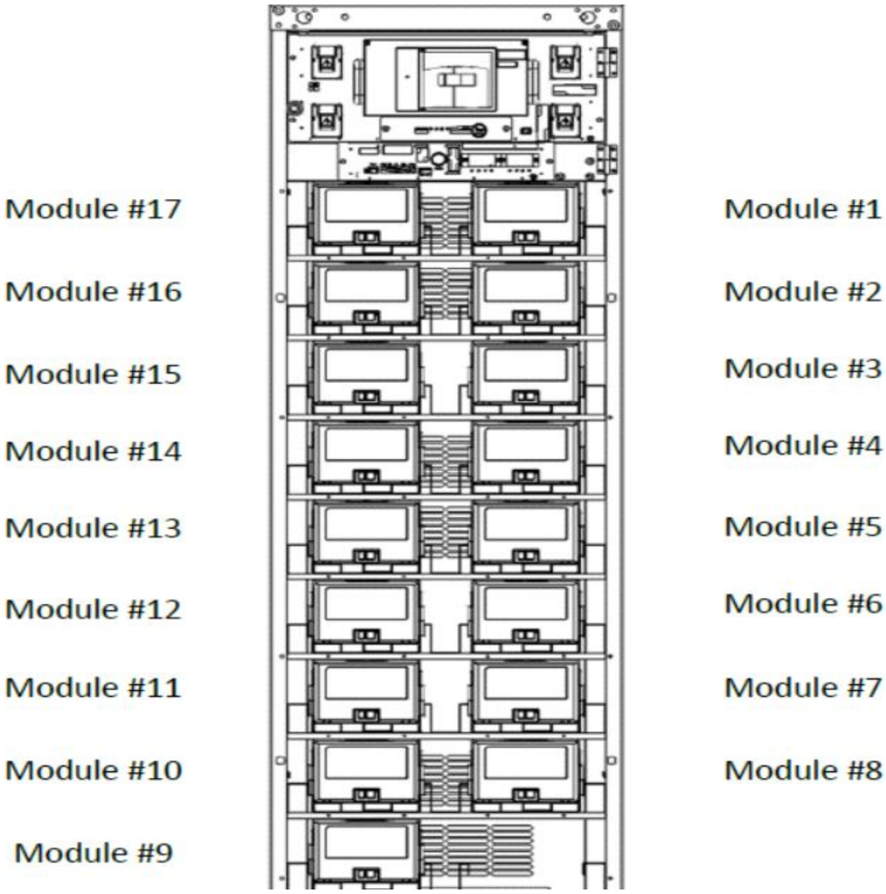


Figure 3. Rack Frame with BCU, SMPS, and Battery Modules Populated

Samsung SDI Lithium Battery Technical Specification

Table 1 presents the technical specifications of the Samsung SDI Lithium Battery used in a 400 kVA Vertiv UPS system. It provides detailed information on the number of modules, nominal capacity, voltage parameters, charging methods, and other key characteristics essential for assessing the battery's performance and operational efficiency. Table 2 presents the technical specifications of the CSB Lead-Acid Battery used in a 400 kVA Vertiv UPS system. It provides comprehensive details on the number of batteries, nominal capacity, voltage parameters, charging methods, and other critical characteristics essential for evaluating the battery's performance and reliability. Table 3 provides a comparative analysis of Valve-Regulated Lead-Acid (VRLA) batteries and Lithium-Ion batteries, highlighting key differences in performance, lifespan, space requirements, weight, temperature sensitivity, and charging speed. This comparison offers valuable insights into the advantages of Lithium-Ion technology over conventional VRLA batteries, particularly in terms of efficiency, durability, and adaptability. The authors in [2] stated in their published paper that Li-ion batteries are primarily used in portable devices such as cellular phones, digital cameras, and tablets. The future of electric vehicles depends on advancements in Li-ion battery technology. Expanding the use of Li-ion batteries will contribute to a more sustainable environment by reducing CO_2 emissions.

Table 1. Technical Specifications of Seventeen (17) Samsung SDI Lithium Batteries Connected to a 400 kVA Vertiv UPS

No	Item	Specification
1	Number of Modules	17
2	Nominal Capacity and Ah	34.6kWh and 67Ah
3	Nominal Voltage and each Battery Voltage	520.2 V DC and 30.4VDC
4	Float Voltage and Each Battery Float Voltage	567.8 V DC and 33.4VDC
5	Discharging Method	Constant Power
	End of Discharge Voltage	390 VDC
	Recommended End of Discharge Voltage	390 VDC
	Standard Discharging Current	22.3A
	Maximum Continuous Discharge Power	183.6kW
6	Charging Method	CC-CV, Floating
	Floating Charging Voltage	571.2V DC
	Standard Charging Current	22.3A
	Maximum Peak Charging Current	958A
	Maximum Continuous Charging Current	67A

Table 2. Forty (40) CSB Lead Acid Batteries Connected to a 400 kVA Vertiv UPS Technical Sheet

No	Item	Specification
1	Number of Battery	40
2	Nominal Capacity in Ah	67Ah
3	Nominal Voltage and each Battery Voltage	480 V DC and 12VDC
4	Float Voltage and Each Battery Float Voltage	540 V DC and 13.5VDC
5	Discharging Method	Constant Power
	End of Discharge Voltage	390 VDC
	Recommended End of Discharge Voltage	390 VDC
	Standard Discharging Current	22.3A
	Maximum Continuous Discharge Power/Current	780A @ 5sec
6	Charging Method	Floating
	Floating Charging Voltage	540.5V DC
	Standard Charging Current	19.5A
	Maximum Peak Charging Current	185A
	Maximum Continuous Charging Current	19.5A

According to [3], high-energy-density lithium-ion batteries (LIBs) are crucial for enhancing the commercial success of electric vehicles (EVs) by extending their driving range. The study conducted a comprehensive review of existing literature focused on improving the energy density of LIBs at the cell level for EV applications, emphasizing material-based design approaches, parameter-based cell design, and LIBs optimization.

Reference [4] highlights that an open-access book provides a comprehensive overview of data science technologies for the full-lifespan management of Li-ion batteries, categorized into manufacturing, operation, and reutilization. The book discusses key challenges, future trends, and promising technologies for improvement. Furthermore, it offers step-by-step guidance, a thorough introduction, and case studies, making it accessible to audiences ranging from graduate students to experienced engineers. It serves as a valuable resource for those interested in battery management.

The authors in [5] specified that energy availability is a significant challenge for space missions, particularly long-term missions. Power sources such as radioisotope thermoelectric generators (RTGs), solar arrays, and batteries have been used to address this issue. Their research explored the application of lithium-ion batteries for long-term space missions. A calendar aging model was developed to assess capacity fade based on temperature, state-of-charge, and time. The results identified the most suitable battery chemistries and optimal conditions particularly at low temperatures to support deep-space missions.

Table 3. Characteristic of Lead Acid /VRLA to Lithium Battery [1]

No	VRLA	Lithium-Ion Vision
1	Unreliable performance	Reliable performance
2	Short life	Long life
3	Requires huge area for installation	Can fit in any space - compact space
4	They are heavy and difficult to move	They can be easily accessed and are not heavy to move
5	Temperature sensitive	Accommodates higher temperature
6	Slow recharge	Fast recharge

In [6], the authors discussed the design of a 120S2P battery with an integrated Battery Management System (BMS) and protection mechanisms. The battery was capable of providing 3.5 kW of power, with a peak output of 5 kW. It was developed using eight BQ76PL455 integrated circuits (ICs) and TM4C123 microcontrollers, with the BMS ensuring power management and the Battery Energy Storage System (BESS) supporting peak shaving in traction drive laboratory power demand.

The study in [7] elaborated on the increasing popularity of electric unmanned aerial vehicles (UAVs) due to their versatility, safety, and cost-effectiveness. UAVs are transforming public services, including real-time surveillance, search and rescue operations, wildlife monitoring, delivery services, wireless connectivity, and precision farming. Hybrid power systems, integrating fuel cells, batteries, solar cells, and supercapacitors, play a crucial role in enhancing UAV efficiency. The research focused on battery-powered UAV platforms that incorporate innovative technologies such as laser beams and tethering, evaluating existing power supply configurations, identifying deficiencies, and providing perspectives and recommendations for future developments.

The authors in [8] pointed out that numerous articles and books have been published on the synthesis and study of advanced materials, circuit and design solutions for control systems, and battery manufacturing. However, only a small fraction of these sources discusses industrially produced materials used in lithium-ion capacitor (LIC) manufacturing, provide data on LIC energy and power parameters, or analyze the characteristics of manufactured miniature LICs, solid-state LICs, lithium metal cells, and all-solid-state cells. Despite the growing interest in these topics, challenges persist in accessing detailed information online due to fragmented data, irrelevant search results, prolonged search times, variations in search engine algorithms, unindexed content, website updates, and the need for additional processing. Their book aimed to systematize and structure information on industrially produced materials for LIC manufacturing and promising LIC applications.

The work in [9] summarized that, over the past few decades, technological advancements have prioritized efficient, socially acceptable, and environmentally sustainable methods for utilizing forestry machinery and tools. These advancements have been facilitated by developments in electronics, electrical components, and battery technology. Today, portable devices such as cell phones and field computers rely on battery technology, simplifying daily life and business operations. The development of lithium-ion batteries recognized with the

Nobel Prize in Chemistry in 2019 has significantly influenced various industries. Their paper explored the historical development of battery technology and its applications in the forestry sector.

Reference [10] further highlighted that Battery Energy Storage Systems (BESS) represent a potential solution for mitigating the intermittency of renewable energy production. Common types of BESS include lead-acid, lithium-ion, redox flow, and sodium-sulfur batteries. These systems play a crucial role in energy management and grid stabilization, supporting renewable energy sources, ensuring energy security in remote communities, and maintaining grid reliability. However, their hybrid nature where zinc plating occurs on the electrode surface during charging may reduce the advantage of decoupling energy capacity from power output.

Finally, the authors in [11] examined the temperature distribution and evolution of both degraded and fresh 18650 Li-ion batteries under different discharging and charging currents. The results indicated that degraded batteries exhibited a higher rate of temperature rise within the first 30 seconds at a 9 A discharging current. In degraded batteries, temperature distribution changed rapidly and stabilized before reaching a Depth of Discharge (DoD) of 0.5, whereas in fresh batteries, the change was more gradual and stabilization occurred after reaching a DoD of 0.5. The differences in temperature distribution and evolution were more pronounced at high currents, while at low currents, they were less noticeable due to increased internal resistance in degraded batteries. These findings suggest that infrared (IR) thermography technology could potentially enable early detection of degraded batteries during high-current discharging.

METHOD

A lithium-ion battery requires minimal maintenance, making it nearly maintenance-free. However, conducting annual inspections of the unit and its installed components is essential and often required for warranty validation. These inspections should include a thorough visual examination of the installation, an analysis of the Battery Management System (BMS) data, and a verification of calibration. When comparing lithium-ion batteries to lead-acid technologies, it is crucial to assess their output during testing. Furthermore, this paper will focus on the specifics of the Samsung Li-ion battery configuration, as it significantly enhances the performance and characteristics of these batteries.

The commissioning of a UPS system with lithium batteries via Modbus communication requires adherence to a specific procedure to ensure seamless integration and optimal performance. First, it is essential to verify that the installed firmware version is 5.0.2 or later, as this enables proper Modbus communication with the Battery Management System (BMS). Additionally, compatibility between the lithium battery and the 400 kVA EXL S1 Vertiv UPS must be thoroughly confirmed to prevent operational issues. This process is particularly crucial for installations utilizing Samsung SDI lithium batteries, ensuring that all components function harmoniously within the system.

A. Hardware Setup

Figure 4 illustrates the hardware setup for integrating a Vertiv UPS, Samsung SDI lithium battery, hub network switch, and laptop during system configuration. The diagram visually represents the interconnections between these components, ensuring proper communication and functionality. The UPS unit is centrally positioned as the primary power management system, interfacing with the Samsung lithium battery pack, which serves as the energy storage unit. A hub network switch is included in the setup to facilitate seamless Modbus TCP/IP communication between the UPS and the Battery Management System (BMS). Additionally, a laptop is connected to the system, allowing users to configure, monitor, and analyze battery performance through specialized software. The setup ensures real-time data exchange, enabling efficient monitoring of key battery parameters such as voltage levels, State of Charge (SOC), and State of Health (SOH). This structured hardware configuration plays a critical role in the commissioning process, ensuring smooth integration and optimal performance of the Samsung SDI lithium battery system with the Vertiv UPS.

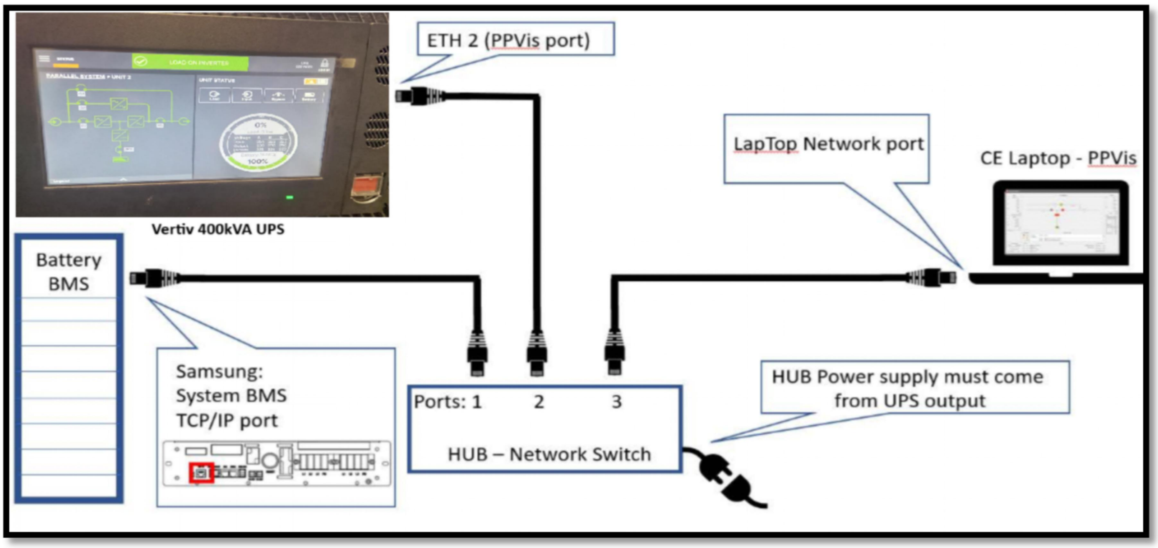


Figure 4. Hardware Setup for Vertiv UPS and Samsung SDI Lithium Battery Integration Using Modbus TCP/IP Communication

B. Software Setup

Samsung SDI Lithium Battery Configuration: Connect the RJ45 cable from the hub network switch port to the BMS TCP/IP port as shown in Figure 5, and configure the settings as shown in Figure 5.

☑	3	[TCPIP] IP Address	169.254.8.142	169.254.8.142	Address
☑	4	[TCPIP] Subnet Mask	255.255.0.0	255.255.0.0	Address
☑	5	[TCPIP] Gateway	169.254.8.141	169.254.8.141	Address

Figure 5. Samsung SDI Lithium Battery Configuration

C. 400 kVA EXL S1 Vertiv UPS to Setup Battery Configuration for Samsung

Figure 6 illustrates the Vertiv UPS software interface used for configuring the battery settings of the Samsung SDI lithium-ion battery system. The graphical user interface (GUI) displayed in the image allows users to access and modify key battery parameters to ensure seamless integration with the 400 kVA EXL S1 Vertiv UPS. Within the configuration panel, users can select the battery vendor in this case, Samsung and input essential network settings, including the IP address and communication port required for establishing a Modbus TCP/IP connection. The interface also provides options to enable or disable a secure connection, ensuring proper communication between the Battery Management System (BMS) and the UPS. This configuration step is crucial for enabling real-time monitoring, optimizing battery performance, and ensuring stable operation of the UPS system. By utilizing this software, users can efficiently manage battery settings, enhance system reliability, and maintain optimal power backup solutions for critical applications.

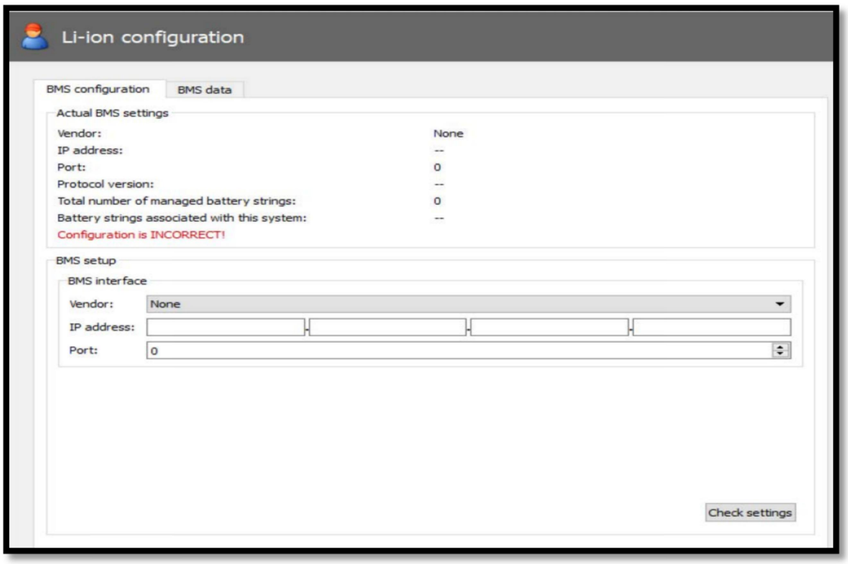


Figure 6. Vertiv UPS software to setup Battery Configuration for Samsung – (1)

D. Complete the following Steps

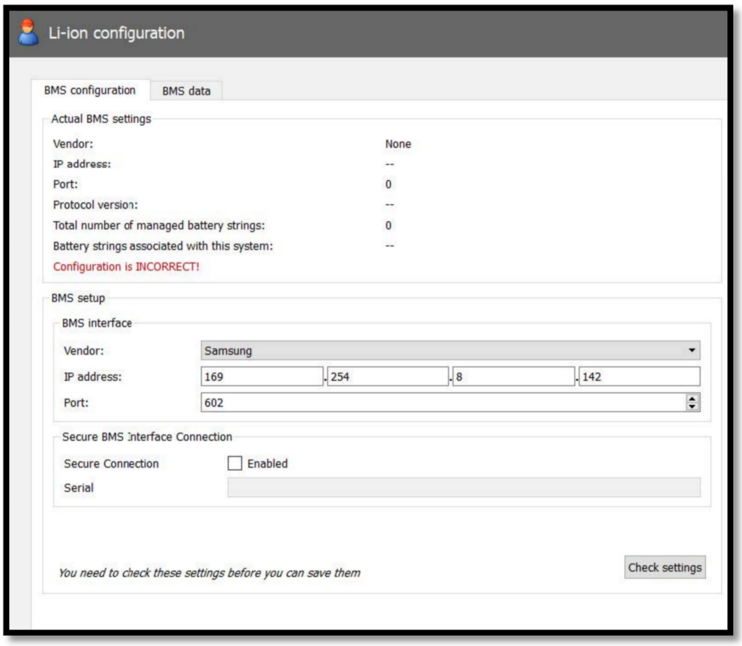


Figure 7. Vertiv UPS software to setup Battery Configuration for Samsung – (2)

Figure 7 presents the Vertiv UPS software interface used for setting up the battery configuration of the Samsung SDI lithium-ion battery system. The interface allows users to input and adjust critical parameters required for seamless communication between the UPS and the Battery Management System (BMS). In the displayed configuration panel, users can specify the battery vendor (Samsung), assign the IP address (169.254.8.142), and set the communication port (602) for establishing a Modbus TCP/IP connection. Additionally, the interface includes an option to disable the secure connection, ensuring uninterrupted data exchange between the UPS and the battery system. This setup process is essential for enabling effective battery monitoring, optimizing power management, and maintaining system reliability. By configuring these parameters correctly, users can ensure that the Samsung SDI lithium-ion battery operates efficiently within the 400 kVA EXL S1 Vertiv UPS system, providing stable and reliable backup power for critical applications Enter IP Address = 169.254.8.142.

E. Save and Start Communication

Click the Save and Start button to save your settings and initiate communication between the UPS and the batteries, as shown in Figure 8.

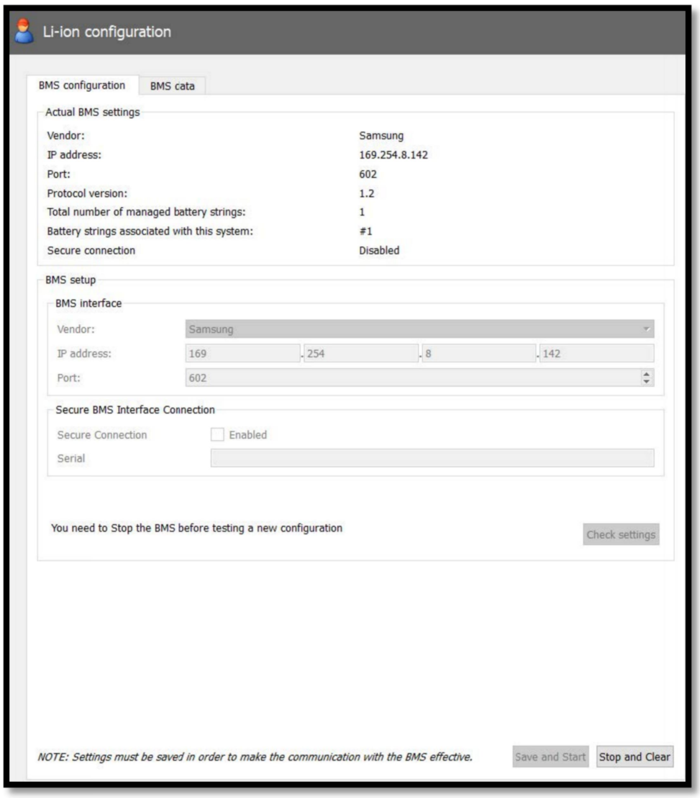


Figure 8. Vertiv UPS software to setup Battery Configuration for Samsung – (3)

To successfully establish communication between the UPS and the battery system, it is essential to ensure that all configurations are properly set. Once all necessary parameters, such as battery vendor selection, IP address, and communication port settings, have been entered correctly, the next crucial step is to save and activate the connection. By clicking the "Save and Start" button, the system stores the configured settings and immediately initiates communication between the Vertiv UPS and the Samsung SDI lithium-ion battery system. This process enables seamless data exchange between the Battery Management System (BMS) and the UPS, allowing real-time monitoring and control of critical parameters such as voltage levels, state of charge (SOC), and system health. As shown in Figure 8, this step ensures that the UPS recognizes the battery configuration, enabling smooth integration and optimized performance for uninterrupted power backup applications.

F. Verify BMS Data

To access and monitor critical battery parameters, the BMS Data tab must be selected from the top menu of the UPS interface. This tab provides detailed insights into the battery management system (BMS), displaying real-time data such as voltage, current, state of charge (SOC), state of health (SOH), and temperature readings of the lithium-ion battery system. By navigating to this section, users can analyze the performance of the battery modules, detect any abnormalities, and ensure optimal operation of the power backup system. As shown in Figure 9, selecting the BMS Data tab enables efficient monitoring and control, allowing system operators to make informed decisions regarding battery maintenance, load balancing, and overall UPS efficiency. This step is crucial for maintaining a stable and reliable power backup system, particularly in data centers and critical power applications where uninterrupted energy supply is essential.

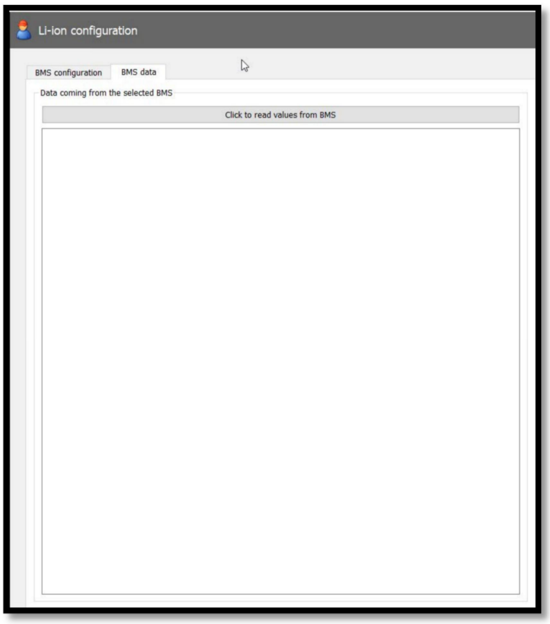
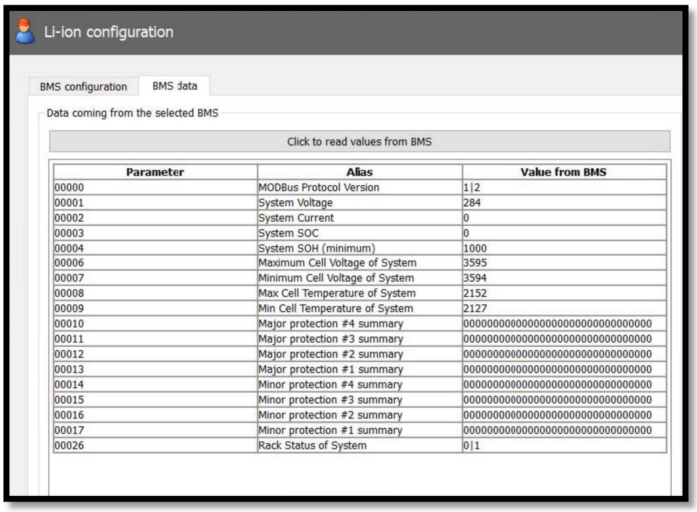


Figure 9. Vertiv UPS software to setup Battery Configuration for Samsung – (4)

G. Click on the BMS icon to read all the battery readings/parameters



Parameter	Alias	Value from BMS
00000	MODBus Protocol Version	1|2
00001	System Voltage	284
00002	System Current	0
00003	System SOC	0
00004	System SOH (minimum)	1000
00006	Maximum Cell Voltage of System	3595
00007	Minimum Cell Voltage of System	3594
00008	Max Cell Temperature of System	2152
00009	Min Cell Temperature of System	2127
00010	Major protection #4 summary	00000000000000000000000000000000
00011	Major protection #3 summary	00000000000000000000000000000000
00012	Major protection #2 summary	00000000000000000000000000000000
00013	Major protection #1 summary	00000000000000000000000000000000
00014	Minor protection #4 summary	00000000000000000000000000000000
00015	Minor protection #3 summary	00000000000000000000000000000000
00016	Minor protection #2 summary	00000000000000000000000000000000
00017	Minor protection #1 summary	00000000000000000000000000000000
00026	Rack Status of System	0|1

Figure 10. Communication Successful between Vertiv UPS and Samsung Li-ion Batteries

H. Vertiv UPS Samsung Li-ion Battery (Resistive Dummy Load Testing)

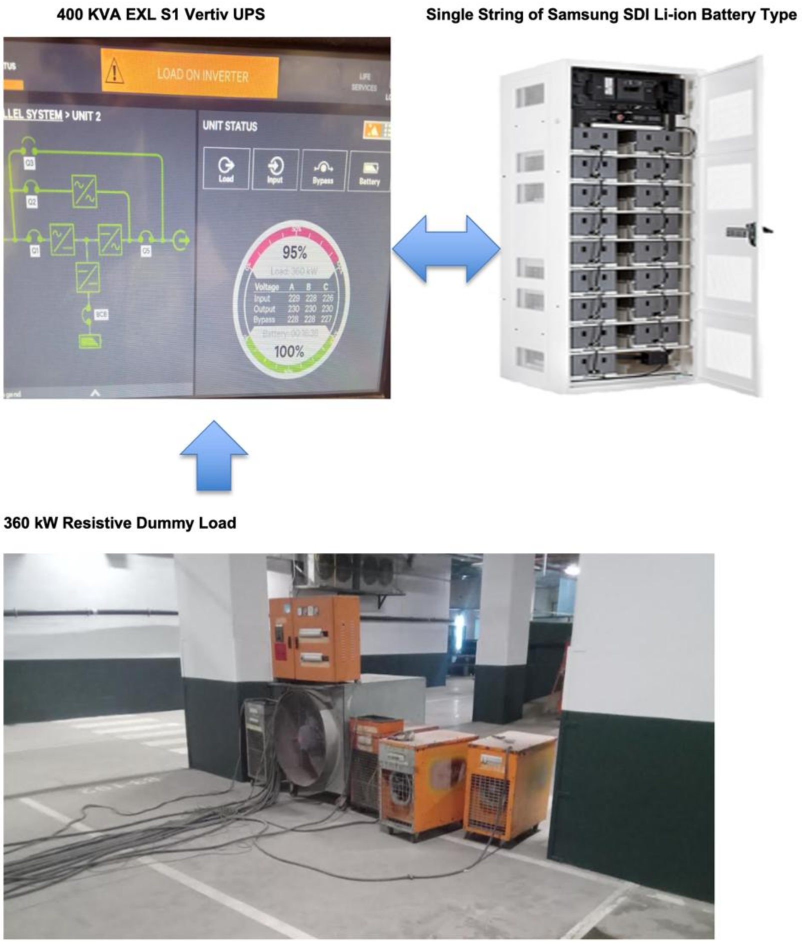


Figure 11. Resistive Dummy Load with Samsung SDI Battery connected to a 400 kVA Vertiv UPS during testing

I. Vertiv UPS CSB Lead-Acid Battery (Resistive Dummy Load Testing)

Figure 11 illustrates the resistive dummy load testing setup for a Vertiv UPS connected to a Samsung SDI lithium-ion battery system. The image showcases the test environment where a 400 kVA Vertiv UPS is integrated with Samsung SDI lithium-ion batteries, arranged in a robust rack configuration. During the test, a 360 kW resistive load is applied to the UPS output to simulate real operating conditions and evaluate the battery system's performance under high-power demand. The setup is designed to assess critical parameters, including battery discharge time, voltage stability, and overall efficiency during power failure scenarios. In the test procedure, an external mains failure is simulated by disconnecting the power supply to the UPS, forcing it to rely solely on battery backup. A timer is used to meticulously record the total discharge duration, allowing for an accurate comparison of lithium-ion battery performance against alternative energy storage solutions. The structured layout of the test environment ensures precise data collection and analysis, reinforcing the suitability of Samsung SDI lithium-ion batteries for high-performance UPS applications in data centres and critical power systems.

Figure 12. Resistive Dummy Load with Lead Acid Battery Type connected to a 400 kVA Vertiv UPS during testing

Figure 12 illustrates the testing setup for evaluating the performance of a CSB Lead-Acid Battery system when integrated with a 400 kVA Vertiv UPS. The test setup is designed to analyse the battery's discharge characteristics, efficiency, and runtime under a 360 kW resistive dummy load. The lead-acid battery bank is connected to the Vertiv UPS, simulating real-world operational conditions. During the test, an external mains failure is induced by disconnecting the primary power supply to the UPS, forcing the system to rely solely on the battery backup. A timer is used to accurately record the end-of-discharge time, providing a direct comparison between the lead-acid battery system and the Samsung SDI lithium-ion battery system. The objective of this experiment is to evaluate the voltage stability, discharge current, and overall runtime of the lead-acid battery under load. The test results help determine the efficiency and viability of CSB Lead-Acid Batteries for UPS applications, particularly in data centres and critical power backup systems.

RESULT AND DISCUSSION

A 400 kVA Vertiv UPS was successfully connected to a string of 17 Samsung SDI batteries arranged in a rack. Each battery delivered a voltage of 30.4 Vdc and had a capacity of 67 Ah, as detailed in Table 1. Following this, we conducted equivalent tests with a Lead Acid battery type, specifically utilizing one string of 40 CSB batteries rated at 12V and 67Ah, referenced in Table 2. Both tests were executed under resistive load conditions, simulating a full load of 360 kW, which constitutes 92 to 95% of the UPS's connected load. Effectively simulated an external mains failure by switching off the supply to the UPS and set an external timer to precisely record the total discharge time during testing. The setup diagrams are provided in Figures 12. The results from the Samsung Li-ion battery type were definitive: the battery capacity reached 0.0%, with a remaining time of 0.0 minutes. The cutoff occurred at 393 VDC under a discharge current of 966.8 A. Figure 13 illustrates the Battery Discharge Curve chart above visually represents the voltage, discharge current, and summed current behavior over a 60-minute discharge period. The x-axis represents time in minutes, while the y-axis represents voltage (V) and current (A).

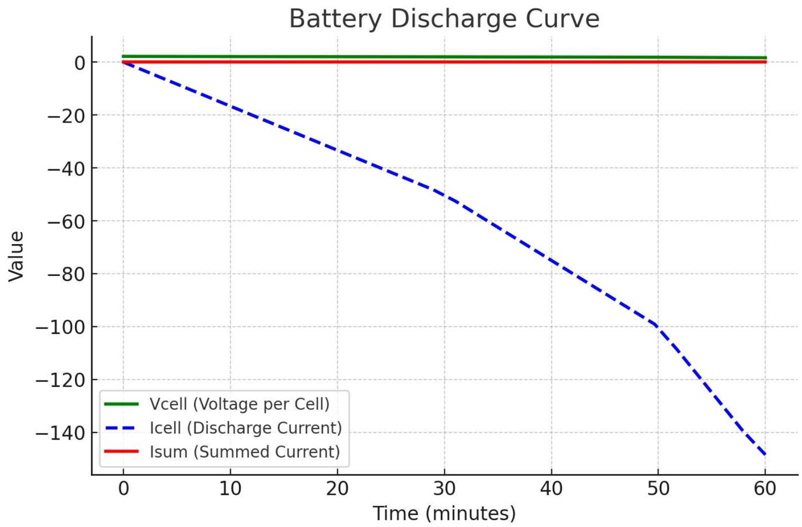


Figure 13. UPS HMI depicting Battery End of Discharge Curve and timer for Li-ion Battery

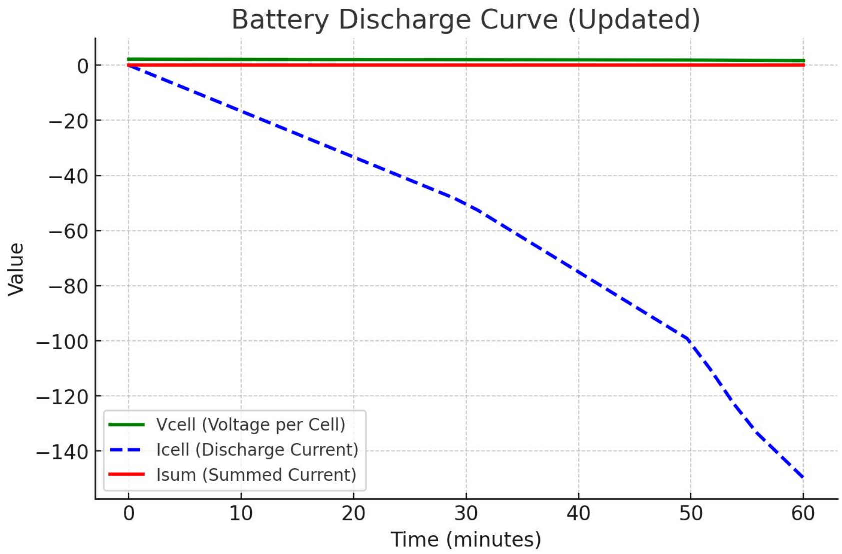


Figure 14. UPS Display HMI depicting Battery End of Discharge Curve and timer for Lead Acid Battery

The results for the Lead Acid Battery type indicate that the battery capacity reached 0.0%, with a remaining time of 0.0 minutes. The cutoff occurred at 395 VDC with a discharge current of 962.8 A. This research firmly establishes a clear comparison between the characteristics of the Samsung SDI Li-ion battery system and those of a Lead Acid Battery system. The findings reveal that the Samsung SDI product is a lithium iron phosphate battery specifically engineered to enhance Vertiv UPS technology, delivering reliable backup energy storage. It is fully compatible with both midline and non-midline UPS products. Additionally, the Samsung battery excels in supporting multi-cluster parallel connections, effectively meeting the configuration demands of UPS systems with diverse capacities. Figure 14 illustrates the Battery Discharge Curve (Updated) chart provides a clear visualization of the voltage, discharge current, and summed current behavior over a 60-minute discharge cycle. The x-axis represents time in minutes, while the y-axis represents voltage (V) and current (A). The chart is designed to analyze the performance of the Samsung SDI lithium-ion battery system during a full discharge event. The Samsung battery boasts significant features, including intelligent pairing with UPS products. It can seamlessly communicate with the UPS via RS485 and dry contacts, facilitating real-time data exchange for intelligent protection and monitoring. Furthermore, it provides independent operation and maintains battery cluster security even when UPS communication is compromised. This product guarantees manageable, predictable, and uninterrupted energy storage specifically designed for critical applications. The Battery Management System (BMS) of the Samsung Li-ion battery cluster utilizes both AC and DC power supplies within the battery, ensuring optimal performance. The BMS prioritizes the use of AC power from the mains during operation and swiftly switches to the DC power supply from the battery string whenever mains power becomes unreliable.

CONCLUSION

This paper aims to compare the Samsung Li-ion battery with a lead-acid battery, focusing on their compatibility with a Vertiv UPS in terms of implementation and operation. The analysis of technical specifications for the Vertiv UPS, Samsung batteries, and lead-acid batteries demonstrates that both battery types are suitable for effective implementation and performance evaluation. The results confirm that both the Samsung SDI Li-ion battery and the lead-acid battery are fully compatible with the Vertiv UPS. However, rigorous testing of deep battery discharge under varying resistive loads connected to the UPS output reveals that the Samsung SDI Li-ion battery outperforms the lead-acid battery, particularly in terms of run-time, as shown in Figures 15 and 17. Based on the findings, the data clearly indicate that the most effective solution for ensuring reliable backup power in data centers is to integrate the Samsung SDI Li-ion battery with the Vertiv UPS unit.

REFERENCES

[1] T. S. Sithole, V. R. Veeredhi, and T. Sithebe, "Factory test of a TP-100 lithium-ion vision battery system for possible implementation in Soweto, Johannesburg, South Africa," Eng. Technol. Appl. Sci. Res., vol. 13, no. 3, pp. 10984–10988, 2023.

[2] V. M. Alexe, "Portable lithium-ion battery UPS with BMS function for Raspberry Pi and other IoT embedded systems," J. Sci. Arts, vol. 22, no. 3, 2022.

[3] F. M. N. U. Khan, M. G. Rasul, A. S. M. Sayem, and N. K. Mandal, "Design and optimization of lithium-ion battery as an efficient energy storage device for electric vehicles: A comprehensive review," J. Energy Storage, vol. 71, p. 108033, 2023.

[4] K. Liu, Y. Wang, and X. Lai, Data Science-Based Full-Lifespan Management of Lithium-Ion Battery: Manufacturing, Operation and Reutilization. Springer Nature, 2022.

[5] H. Ali, H. Beltran, N. J. Lindsey, and M. Pecht, "Assessment of the calendar aging of lithium-ion batteries for long-term space missions," Front. Energy Res., vol. 11, p. 1108269, 2023.

[6] L. Streit, T. Košan, and J. Hammerbauer, "CAN controlled 120 cells Li-Ion battery with integrated BMS and protection," in Proc. 20th Int. Conf. Mechatronics-Mechatronika (ME), 2022, pp. 1–4.
[7] Y. N. Saravanakumar et al., "Power sources for unmanned aerial vehicles: A state-of-the-art," Appl. Sci., vol. 13, no. 21, p. 11932, 2023.
[8] Y. Koshtyal and A. Rumyantsev, Lithium-ion cells: Materials and Applications. 2024, p. 398.
[9] Z. Pandur, M. Šušnjar, and M. Bačić, "Battery technology–use in forestry," Croat. J. For. Eng., vol. 42, no. 1, pp. 135–148, 2021.
[10] D. Bryans, M. R. Jiminez, J. M. Maxwell, J. M. Mitxelena, D. Kerr, and L. E. A. Berlouis, "Standalone batteries for power backup and energy storage," in Adv. Energy Storage: Latest Developments from R&D to the Market, 2022, pp. 31–60.
[11] S. Ni, S. Lama, Y. J. Lee, and J. H. Kim, "Early detection of secondary battery degradation by infrared technology: An experimental study," Arab. J. Sci. Eng., vol. 49, 2024, pp. 1–14.

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